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RESOLVING LATERAL SEGREGATION EFFECTS OF STATIC BLENDERS

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Abstract. To date static blenders have mainly been used for mixing fluids, but recent research has shown the potential of static blenders for blending powders and granular materials as well. A problem when using a static blender in conjunction with powders and granular materials is trajectory induced segregation at the output of the blender. In order to evaluate the blending process two granular materials exhibiting extreme particle densities and sizes have been discharged into a static blender. The blend is collected in a radially compartmentalised receiving container and the blend composition of each compartment is then analysed. This paper presents a simple counter measure to reduce the effect of trajectory induced segregation. In addition this research has shown that, contrary to expectations, an increased number of blending stages does not necessarily bring improvements in homogeneity of the output stream. The results presented in this paper are of special interest to anyone blending powders and granular materials in an industrial environment.

1 INTRODUCTION

The benefits of using static blenders are numerous for industry; low energy consumption, continuous operation, reduced blender wear when handling abrasive materials and potentially higher time averaged throughput. Despite the numerous benefits, static blenders are not yet widely used in conjunction with powders and granular materials. This lack of technology uptake is attributed to a lack of thorough understanding of the mechanisms of the static blending process. Static blenders usually consist of several identical blending stages arranged above one another with alternating orientations. Each stage contains one or more baffles such that the descending particulate material is encouraged to interact and blend. There are many design parameters to be considered when analysing a static blender; the spatial arrangement of the baffles, the number of stages, the height of each stage, the relative orientation of consecutive stages, the material bulk properties, material feeding rate and the discharge location of the feed relative to the first blending stage. One of the issues which arises when using a static blender in conjunction with binary mixtures exhibiting extreme particle densities and sizes is trajectory induced segregation at the output of the blender. Trajectory induced segregation occurs when particles have different energies and/or different drag coefficients. To overcome this issue this paper proposes a simple counter measure and has analysed the influence of the number of blending stages on the homogeneity of the output. The presented results are an outcome of an industrial feasibility study to determine the potential of a static blender used in conjunction with a binary mixture of granular materials exhibiting extreme particle densities and sizes.

This research made use of a custom designed static blender which has the flexibility to easily alter the number of blending stages. In order to analyse the lateral homogeneity at the output of the blender the granular material is collected in a radially compartmentalised receiving container. After each test run, the blend composition of each individual compartment is analysed. In addition to varying the number of blending stages a combination of funnels is employed at the output of the blender in an attempt to homogenise the blend. The results show that by using a combination of a conventional funnel and a slotted funnel together with two blending stages the best results are obtained. Surprisingly it was found that having two blending stages instead of four blending stages produced the best results in terms of homogeneity around the discharge area.

2 METHOD

Two granular materials which differ extremely in density and size are used in this research. The first granular material (X) has a density of 0.9 $g \cdot cm^{-3}$ and the second granular material (Y) has a density of 4.6 $g \cdot cm^{-3}$. The respective size distributions are tabulated in Table 1. The tables clearly indicate there is no overlap between both size distributions which means both granular materials can easily be separated again by using a single sieve for analysis. Unfortunately due to confidentially restrictions no further information about the granular materials can be provided. According to the specifications of the industrial collaborator a blend composition of 20% of material X and 80% of material Y in terms of weight is used. In terms of volume this roughly relates to equal parts of both materials.

Both granular materials are discharged into the static blender from a split feed pipe

Table 1: Size distributions as % retained

(a) Granular material X

Sieve size	Retained (%)
Fines	1
250 μm	2
355 μm	36
500 μm	29
630 μm	11
710 μm	18
850 μm	3
1.18 mm	0

(b) Granular material Y

Sieve size	Retained (%)
Fines	0
1.40 mm	0
1.70 mm	7
2.00 mm	93
2.80 mm	0
3.35 mm	0

and are collected in a radially compartmentalised receiving container with eight compartments. The split feed pipe has two calibrated orifices at the bottom which are uncovered simultaneously at the beginning of each test run. The orifices are calibrated such that an approximate 20/80% weight flow occurs. The contents of each individual compartment are sieved and the weight ratio as a percentage of granular material X is determined. A schematic overview of the experimental set-up and the actual realisation can be seen in Figure 1. The photograph of the actual set-up does not show the funnels but it does show the compartmentalised receiving container at the bottom.

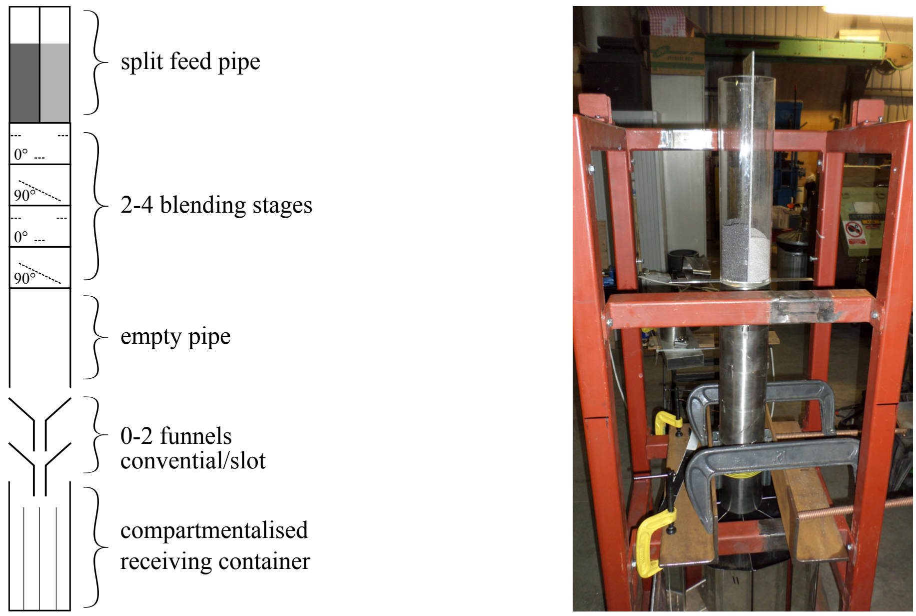
To influence the blend quality the number of blending stages is varied and a combination of funnels is used at the output of the blender. Two funnel types are considered, a conventional funnel and a slot type funnel. The test conditions are given in Table 2, note that test 1 and 2 are the same and that test 6 and 7 are the same, this is to validate the repeatability and consistency of the results. All testing is undertaken at ambient laboratory conditions.

Table 2: Test conditions

Reference	Blending stages	Conventional funnel	Slot type funnel
1	4	-	-
2	4	-	-
3	4	X	-
4	4	X	X
5	3	X	X
6	2	X	X
7	2	X	X

Figure 1: Experimental set-up

(a) Schematic overview (b) Actual set-up



The static blender used in this research has been previously applied in a PhD study at the Wolfson Centre [3]. Each blending stage has an internal diameter of 103 mm and a height of 100 mm. The static blender has a modular set-up such that the number of blending stages can be altered easily. Each blending stage contains three baffles in a configuration similar to the Sulzer [4] type of static liquid blenders. During the tests the blending stages are stacked with alternating orientations of 0° and 90°. Two identical blending stages can be seen in Figure 2. The figure shows the configuration of the three baffles, a central finger protruding at an oblique angle and two perpendicular ridges attached to the walls.

The outlets of the feed pipe are obscured before completely emptying the feed pipe, this is to avoid potential granular material collapsing at the end which could lead to a disrupted flow. Separating both granular materials again is done by using an Endecotts woven wire laboratory test sieve with an aperture of 1.7 mm. After separation both granular materials are weighed using a Sartorius MSU14202P-000-D0 balance.

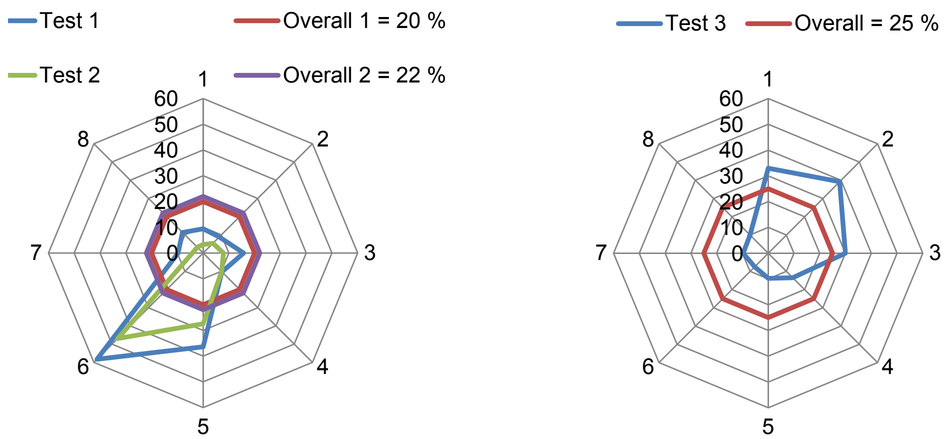
3 RESULTS

The data of each test runs is visualised using a radar graph, each point on the graph corresponds to the blend composition of granular material X as %wt of one of the eight compartments. Each radar graph also shows the overall blend composition. The weight of granular material X discharged during the experiments ranged between 0.8 kg and 1.0 kg and for granular material Y this range was between 2.5 kg and 3.7 kg. The radar

Figure 2: Two identical static blending stages

Figure 3: Content (% wt) of granular material X

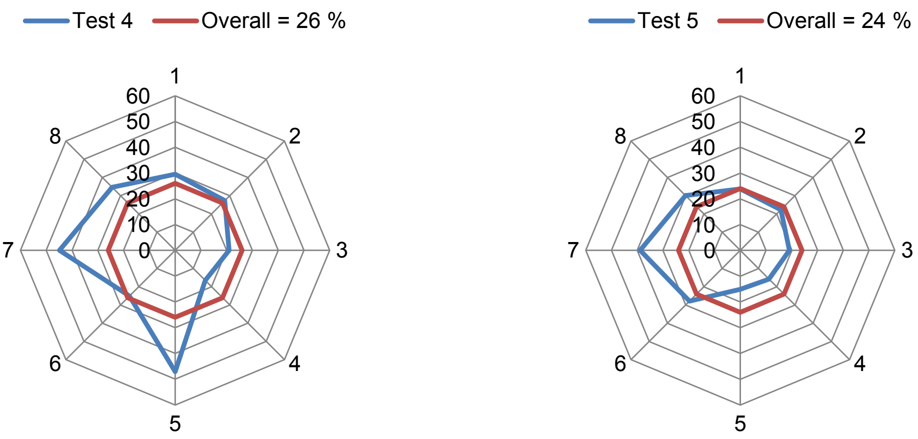
(a) Test 1&2 (b) Test 3



graph in Figure 3a show a strong lateral deviation from the average composition. This can partially be attributed to the final trajectory imparted by the last blending stage. As a counter measure, a regular funnel was installed below the static blender to centralise the deposition of the material. The result can be seen in Figure 3b and shows a slight improvement compared to the initial condition. It can be seen that the blend composition has shifted by 180° which means the material flow is highly susceptible to the rebound effect. To further limit the rebound effect, it was decided to interpose a slotted funnel above the regular funnel. The result of this modification can be seen in Figure 4a, it shows a slight improvement, but still the blend composition was very inconsistent around

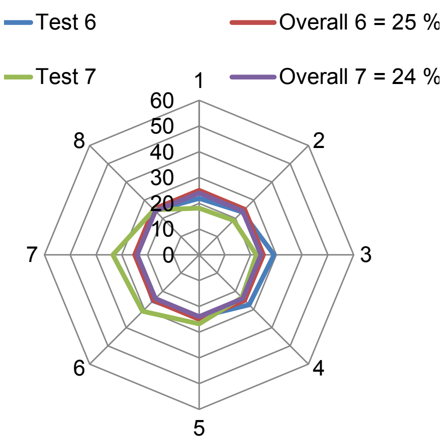
Figure 4: Content (% wt) of granular material X

(a) Test 4 (b) Test 5



the deposition area. Next it was decided to reduce the number of blending stages from

Figure 5: Content (% wt) of granular material X



four to three, which gave a more controlled deposition as can be seen in Figure 4b. The number of blending stages was finally reduced to just two, which gave the results shown in Figure 5. Using this final configuration the composition around the discharge area is consistent.

4 DISCUSSIONS

The results presented in this paper are preliminary and give rise to many more research questions. One of the issues with the results presented in this paper is that due to time constraints some of the test runs have not been repeated. Currently the feeds operate in core flow which might cause disruptions during discharge due to wall friction [1]. To obtain more reliable results a feed which operates in mass flow could be used, in addition the feed rates need to be better controlled as the blend composition varied between 20% and 26%. Another issue regarding the feed is the location where the granular materials will be discharged relative to the first blending stage. It can be expected that by discharging materials directly above the protruding finger of the static blender the contribution of the first blending stage will be small.

The design and geometry of the static blender used in this research is rather arbitrary, no valid motivation can be provided as why this specific blender has been chosen other than the fact a similar blender has been used in a previous study [3]. There are a large number of parameters governing the performance of the blender such as the diameter of the blender and the configuration of the baffles inside the blender. More research is needed on how to incorporate these parameters in the design process of a static blender.

The issue of trajectory induced segregation has been noticed in a previous study by Salter et al. [2]. His paper mentions a diffusive stage to radially homogenise the discharging mixture stream. In future work it would be interesting to see if this diffusive stage can also be used in conjunction with extreme particulate blends. Another aspect worth investigating is the contribution to the blending performance caused the arrangement of funnels, this can be done by omitting the static blender from the set-up. The research presented here has focused on a single binary blend of granular materials, further research is needed to verify if the results obtained are also applicable to other blends of particulates. It can be argued that by having smaller differences in density of the granular materials entering the blender the effects of trajectory induced segregation will be smaller.

5 CONCLUSIONS

This paper has shown that the issue of trajectory induced segregation occurring at the output of a static blender can be controlled using a simple combination of funnels. In addition this research has shown that, contrary to expectations, an increased number of blending stages does not necessarily bring improvements in homogeneity of the output stream. The results presented in this paper are relevant for any industry that blends powders or granular material as part of their process. The presented method to analyse the homogeneity around the discharge area is a valuable contribution to enhance the uptake of static blenders in industrial processes.

As the nature of this research is preliminary there are still many open research questions, such as:

- Is the design and geometry of the static blender used an optimal one ?
- Are the results presented also applicable to blending other particulate materials ?
- How does the material feed rate influence the blend quality ?

- How does the material discharge location influence the blend ?

Finally the effect of material properties such as size, cohesiveness and density on the blend quality and blending performance should also be considered in future research.

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